THE FLORA OF THE SWISS ALPS[1]

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I.

The extensive range of the European Alps forms an arch covering a distance of 750 miles from Genoa to Vienna. It comprises a series of folds of geologically recent formation; it dates from the beginning of the Tertiary period. The Swiss Alps occupy almost the center of the arch. The divisions of the Swiss Alps in horizontal regions are determined, first, by the geological nature of the soil, and, secondly, by the climate. If we glance at a geological map of the Alpine range showing a few outlines, we perceive a center of primitive siliceous rocks, the Central Alps. This center is bordered on the south and on the north by a fringe of calcareous sediments, first of Mesozoic, then, toward its margin, of Tertiary age. The Prealps are therefore formed principally by calcareous soils, nourishing a calciphilous vegetation; the Central Alps consist of siliceous rocks, occupied by a limestone-avoiding flora.

In addition to this geological difference between Central Alps and Prealps, we have a climatical one in this sense, that the Prealps show a more oceanic climate with mitigated extremes, the Central Alps are more continental with pronounced extremes. This accounts for the fact that the two trees of continental character, the Larch (*Larix decidua* Mill.)[2] and the Stone or Arolla Pine (*Pinus cembra* L.), are confined to the Central Alps.

A third difference between Prealps and Central Alps is accounted for by the difference in altitude of the upper limit of the growth of trees and of the under limit of eternal snow. It is a general law that in great mountain masses all limits are found at a higher level than in isolated chains. (This is clearly indicated by the picture showing the situation of the snow-line in the different parts of Switzerland. All the points with identical altitude are joined by a black line, called an isochion.) In the region of the northern Prealps the snow-line lies at 8,000 feet, and toward the Central Alps it rises higher and higher; in the Engadine Alps it is situated at 9,300 to 9,600 feet, in the great masses of the Pennine Alps (Monterosa) even at 10,000 feet. Similar differences show the upper limit of tree-growth, and in general all the limits of plant life.

From this fact, combined with the warm summer and historical causes, originates the great variety of the flora of the Wallis and the Engadine; if you want to spend your holidays in the countries richest in alpine flowers, you are to go to Zermatt or to Pontresina.

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[1] Lecture delivered before the Society, Sept. 12, 1913.

[2] Nomenclature after Schinz and Keller, Flora der Schweiz, 3 ed. 1909.

These are the regional subdivisions of the Alps; in wandering from the Prealps to the Central Alps, we meet first limestone plants, oceanic ones and low limits, then in the Central Alps limestone-avoiding plants, continental ones and high limits. But still more pronounced than these regional differences is the change in vegetation as we ascend toward the mountains from the lowlands. Switzerland, although a small country, contains within its boundaries all the vegetations of Europe from the mild Mediterranean region to Spitzbergen and Lappony! We are able to wander through an extent of thirty degrees of latitude in the course of *one* day, in climbing, for instance, from Siders in the hot valley of Wallis (1,450 ft.) up to the Gornergrat near Zermatt (10,000 ft.). The change in vegetation is extremely gradual, but nevertheless we can divide it into four well-defined zones, or belts.

The first, comprising the Lowlands, extends to the upper limit of the vineyard; above 1,500 or 2,000 feet the grape will not ripen; only in Wallis, in the masses of the Pennine Alps, the vineyards reach up to 4,000 feet.

Then follows the light-green belt of the deciduous forests, the domain of deciduous trees, the mountain belt, or beech belt, surrounding like a garland the foot of the Alps, reaching to about 4,500 to 5,000 feet above the sea.

And now we enter the dark-green coniferous belt, the subalpine belt, where the Spruce (*Picea excelsa* Link), the Larch, and the Arolla Pine form dense woods, reaching upward to the upper limit of tree-growth. Here already alpine conditions of life begin to rule. At 6,000 to 9,000 feet lies the tree limit.

Above this belt begins the true alpine (the treeless) belt, the kingdom of pastures and meadows, of rock, screes, snow and ice. But the plant life has conquered the whole belt and climbs to the highest peaks wherever a place exists free of snow.

The extreme altitude at which a flowering plant has been found in Switzerland is 14,250 feet above the sea-level; it is the glacial buttercup (*Ranunculus glacialis* L.), which ascends to this altitude in the Finsteraarhorn in the Bernese Oberland. Eight species[3] of flowering plants exist above 13,200 feet, more than three hundred in the whole snow-belt above the under limit of perennial snow.

Still more resistant than the higher plants are the cryptogams, especially the lichens; over one hundred kinds of these plants are found above 11,300 feet, and six different kinds[4] cover the top of

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[3] *Ranunculus glacialis* L.; *Achillea atrata* L.; *Androsace alpina* (L.) Lam.; *Saxifraga aspera* L. var. *bryoides* L.; *Sax. moschata* Wulfen; *Sax. muscoides* All.; *Sax. biflora* All.; and *Gentiana brachyphylla* Vill.

[4] *Toninia conglomerata* (Ach.) Zahlbr.; *Rhizocarpon geographicum* (L.) DC.; *Pamelia spec.; Umbilicaria spec.; Lecanora concolor* Ram. var. *angustata* (Arn.) Nyl., with the parasitical lichen *Buellia leptoleptis* Bagl. & Car.

the highest Swiss mountain, the Monte Rosa, at 15,217 feet. There is indeed no real upward limit of vegetation in the Alps.

A short excursion through some characteristic parts of the country will show us the principal steps in the change of the vegetation. We begin in the lake region at the southern foot of the Alps, where we find the mildest climate in Switzerland. At the shores of the lakes of Locarno, Lugano, and Como, the Italian cypress (*Cupressus sempervirens* L.) brings us a greeting from the Mediterranean countries (Fig. 12).

Then we enter the beech forests, and admire the mighty crown of this dominant tree (*Fagus sylvatica* L.) of the mountain belt; the group shown in Figure 13 grows near Flims in the Oberland of Grisons, and is renowned for its luxuriant growth.

From the top of the Piz Mundaun in the same Oberland of Grisons we cast a glance at the slopes of the valley of the Upper-Rhine, where the coniferous belt (*Picea excelsa* Link) is seen in its whole extension, surrounded at its foot by woods of oak, and transgrading upward into the alpine belt (Fig. 14). This dark-green girdle, formerly continuous without any doubt, has been partly destroyed by human action, and shows now many interruptions filled with corn-fields, meadows, and pastures—that is, various culture and semiculture formations.

The Scotch Pine (*Pinus sylvestris* L.) with its flattened crown is the tree of our very poorest soils, where it adorns rocky or sandy slopes, as is shown in our picture taken near the Campodials in the Grisons (Fig. 15).

In the Central Alps, especially in the Upper Engadine and Wallis, the Spruce is upwardly replaced by a tree of the continental climate, the Larch (*Larix decidua* Miller), forming open woods with so slight a shade as to allow the occurrence of a good pasture under the trees. Thus those larchwoods form an ideal solving of one of the most intricate economical problems of the Alps, the cause of an endless conflict between forester and alpine farmer. And at last we admire in the Central Alps, for instance at Zermatt or Engadine, another continental tree, the Arolla Pine, the Siberian Cedar, the king of the alpine trees (*Pinus cembra* L.), which forms often the timber-line (Fig. 16).

And now we reach the limit of tree-growth, this most important biological line, which separates the Arctic region and the alpine belt from milder climates. It is not a line; it is a girdle where the tree struggles for its life (*Kampfzone*, struggle belt). First we leave behind us the continuous wood (Forest-limit), then the isolated pioneers of trees (Tree-limit), and finally the stunted forms of trees (Cripple-limit).

In and above this belt of struggling tree-life lies the belt of alpine shrubs; the Alpenrose (*Rhododendron*), the green Alder (*Alnus viridis* (Chaix) Lam.), and the dwarf Pine (*Pinus montana*

Fig. 12. The Italian Cypress (*Cupressus sempervirens* L. var. *fastigiata*) on the shore of Lake Como near Bellaggio.
Photo Taegar.

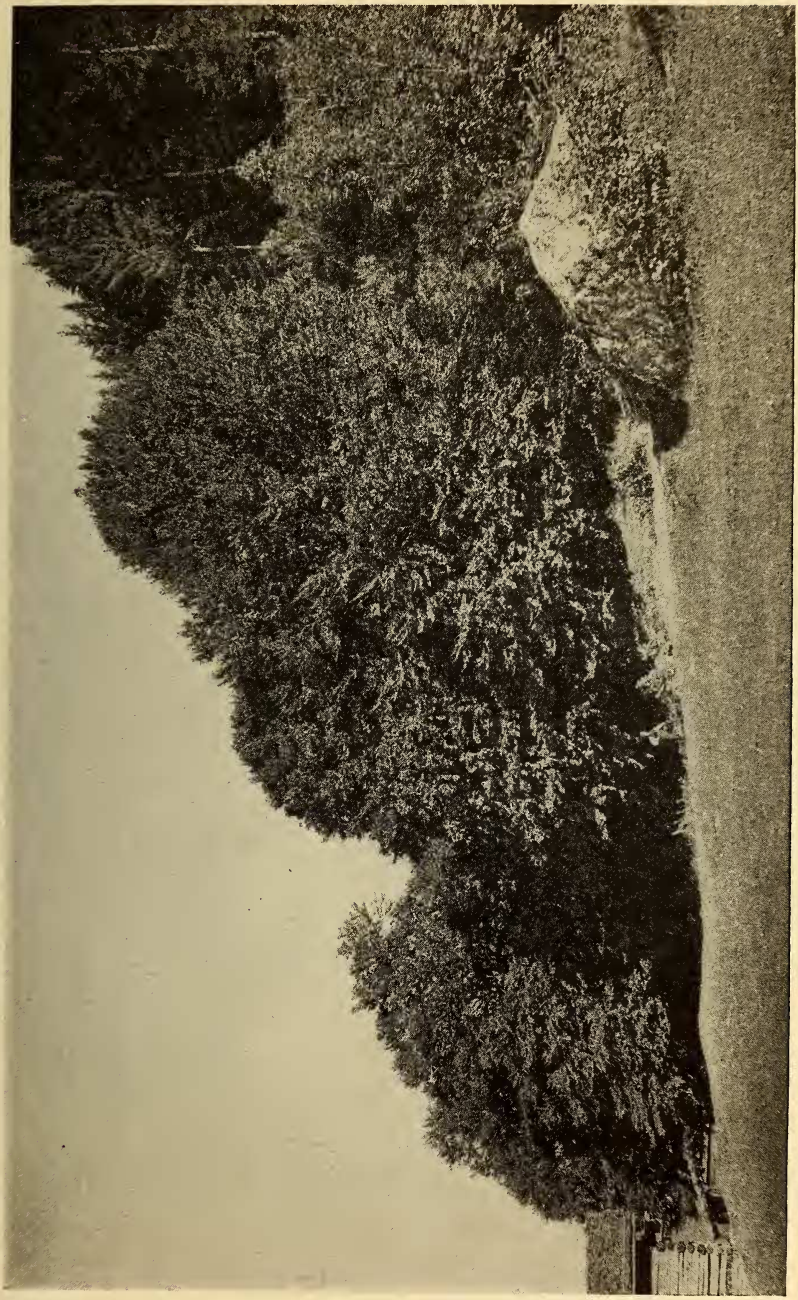

Photo Hager.

Fig. 13. Beeches (*Fagus sylvatica* L.) near Flims, Grisons.

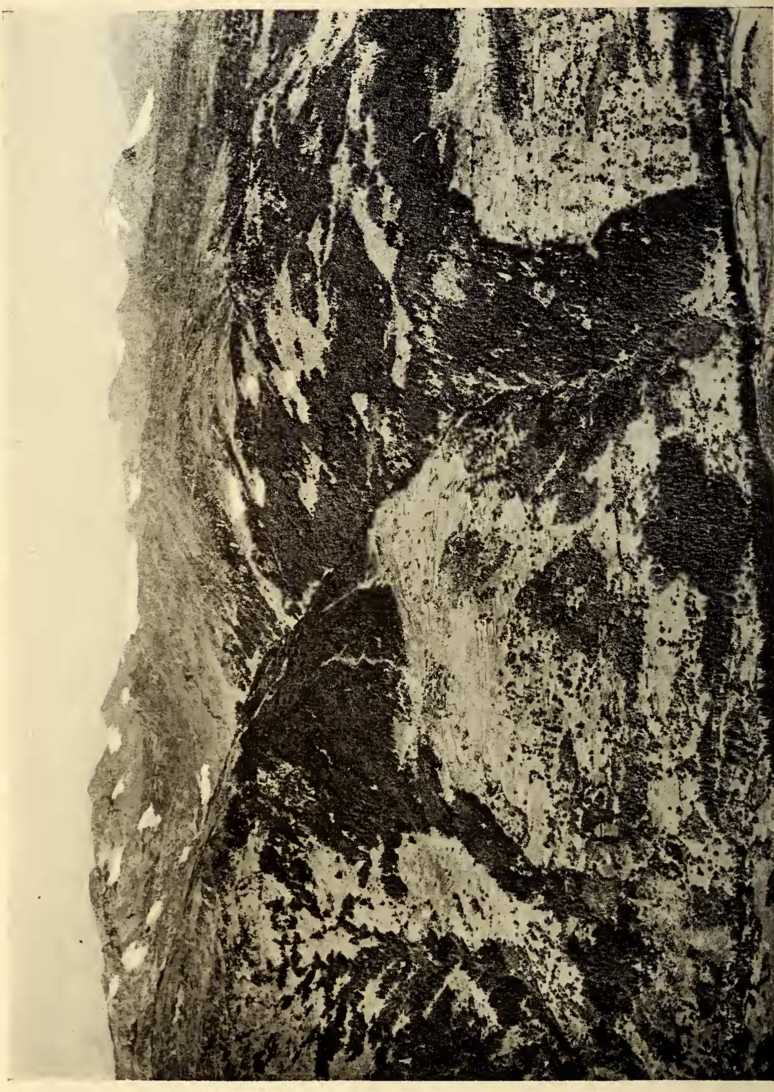

Fig. 14. View from Piz Mundaun, looking north near Ilanz, Grisons. The coniferous belt, consisting of a forest of common spruce (*Picea excelsa* Link), originally covering the whole slope with a continuous forest, is now by human action interrupted by meadows and fields.

Fig. 15. The Scotch Fir (*Pinus sylvestris* L.), near the Campodials, Grisons.
Photo Hager.

Fig. 16. The Arolla Pine (*Pinus cembra* L.) at the timber-line in the Valley of Scarl, in the under Engadine (Swiss National Park). The Arolla Pine never shows low, reduced forms, but reaches its limit in unbroken vigor. Photo Meyer.

Mill. var. *prostrata* Tubeuf) are the dominant elements. We force through these thickets, and now we stand on the free alpine pasture covered with thousands and thousands of bright-colored flowers. "Nothing in the world equals this splendid spectacle," says Dr. Christ; "we hesitate to advance fearing to crush under our feet these delicate beings." In ascending we see by degrees the continuous sward dissolving into isolated green patches. They begin to mingle with white patches of perennial snow, the outposts of the snow-belt, and finally we enter the dominion of eternal snow, the recent glacial period.[5]

II.

Previous to the study of the typical plants of the alpine belt, we will take a brief view of its climate. Its principal features are the following ones:

The shade temperature falls lower and lower as we ascend, but this loss of warmth is more than compensated by the enormous increase of the effects of sunshine. We see this difference in the clearest manner in comparing a thermometer in the shade with a thermometer in the sun. Frankland has made such experiments with the following results: He found at Witby in England (66 feet above the sea), 91° Fahrenheit in the shade, 100° Fahrenheit in the sun, a difference of 9°. At Pontresina, 6,000 feet above sea-level, the sun-thermometer showed already 31.5° Fahrenheit more than the shade-thermometer, and finally at the Diavolezu, at 10,000 feet above the sea, the thermometer showed 43° in the shade, 139.1° in the sun, thus a difference of 96° Fahrenheit. Dr. Rübel found at the Bernina hospice, 8,000 feet above the sea, a still greater difference of 111.6° Fahrenheit, 12.2° in the shade, 122.9° in the sun. Saussure found on Mont Blanc even a difference of 162° Fahrenheit!

This plenty of light and warmth that the alpine sun spreads to the alpine plants is the key to understand their flourishing growth. But there is one great drawback, the shortness of the period of vegetation. The period shortens nine days for every 333 feet of ascending. In the alpine belt it has a decreasing duration of from five months to only three weeks; in this short lapse of time high alpine plants must perform all their biological duties.

On the other hand, this shortness of the vegetation time is a little compensated by another important difference between lowland cli-

[5]Lately, I. Braun, Die Vegetation der Schneestufe in den Rhätische-lepontische Alpen, Ein Bild des Pflanzenlebens an seinen ausseresen Grenzen ("Neue Denkschriften der Schweiz. Naturf. Ges. Band XLVIII. Basel, 1913"), has in an excellent paper proposed the following division of the snow-belt of the Swiss Alps:

Pionirrascu (isolated patches of mats),—up to 150 m. above the snow-line.

Area of Dicotyledons (mostly cushion plants),—up to 550 m. above the snow-line.

Belt of Thallophytes,—from the last Phanerogams to the highest peaks.

mate and alpine climate, namely, the temperature of the air at the time of the melting of snow. This temperature increases with the altitude. Hence it comes that the alpine flora finds a warm air immediately after the melting of snow. So we understand the fact that close to the edges of snow-fields we find the bright colors of alpine spring flowers.

Very important for the growth of alpine plants is the fact that the alpine vegetation begins late in the year, in June or July, when the days are long and the nights are short. Now, you know that it is especially in warm nights that plants grow and shoot their stems, whereas the light of the day favors the production of organic material by means of the energy of the sun-rays. Thus our alpine plants are able to assimilate copiously during the long warm days with their strong insulation; but in the short and often very cool nights they cannot prolongate their stems; hence the dwarf habit of alpine plants; it is a direct effect of climatic favors.

But we must be aware of the fact that there exists another dwarfness, a hereditary one, not directly produced by alpine factors, but favored by natural selection. The dwarf Pine (Krumholz, *Pinus montana* Mill. var. *prostrata* Tubeuf), for instance, remains dwarf even in the lowlands! It is clear that a dwarf habit is very useful to alpine plants in many respects: against the mechanical effects of the thick layer of snow; as a means of protecting the plant against frost and the winter dryness, being covered by snow; and as a means to take advantage of the warmth of the soil.

The mountains are well known as rain and snow catchers; the layer of snow is thick and lasts a long time. How enormous quantities of snow may accumulate at places is shown in a picture taken by Dr. Rübel at the Berninapass, where the stage is driving between snow walls 9 to 12 feet high.

III.

But enough of this preparation: let us now enter the living alpine world and become acquainted with its principal types. We begin with the alpine thicket and its most popular shrub, the Alpenrose, the queen of the alpine flora, which garbs in radiant purple entire slopes. We have two kinds of Rhododendron in our Alps; the two are evergreen shrubs with leathery leaves. The brown one (*Rhododendron ferruginum* L.) has leaves which are brown underneath through glandular scales; the hairy one (*Rh. hirsutum* L.) has very few brown scales, and the edges of its leaves are fringed with long hairs. If the two grow side by side, regularly there arises a natural hybrid: if a busy bee transposes some pollen from stamina of a hairy specimen to stigma of a brown one, there ripens a seed out of which grows an intermediate being which shows a mixture of the characters of both parents. Our alpine roses are old Tertiary pure alpine types restricted to the Alpine range and the Carpathian Mountains; they are near relations of the great Rhododendrons of the Himalaya. They ascend to 7,000 feet; it is very probable that their upper limit is an indication of the former upper limit of trees.

Also the green Alder (*Alnus viridis* (Chaix) Lam.) covers the slopes immediately under and above the actual tree-line with its bright green, helping to fasten slipping ground.

Fig. 17. The Dwarf Pine (*Pinus montana* Mill. var. *prostrata* Tubeuf) covering a grassy slope near Davos; about 2,000 meters above the sea. Photo Wünsche.

The dwarf Pine (*Pinus montana* Mill. var. *prostrata* Tubeuf) (Fig. 17) ranks especially as a pioneer on calcareous slopes; the black masses assaulting the fortresses of moving rubbles in the dolomites of the lower Engadine consist of dwarf pines. With its long flexible twigs, this bush is marvelously adapted to retard avalanches and to protect the soil. These larger shrubs of the shrub-belt are substituted in higher altitudes by stunted little dwarfs, which spread over the ground with horizontal twigs, all in one level like a mat.

A near relation of the Rhododendrons is the trailing Azalea (*Loiseleuria procumbens* (L.) Desv.), which forms a thick carpet on the ground and opens its beautiful little rose-flowers in the beginning of the alpine spring. It has a wide distribution; it is a dominant type in the circumpolar tundra, lives in the Altai, the Pyrenees, the Alps, Carpathian and Balkan mountains. But notwithstanding this wide spreading it has no varieties and is the only spe-

Fig. 18. *Salix herbacea* L. Schematic drawing—vertical section of the ground, representing mode of growth. Male plant at left, with catkins in flower. Female plant at right, with catkins in flower and in fruit. Photo Schröter.

cies of its genus; a classical example of a primeval but nevertheless still vigorous type with great power of expansion.

All these alpine shrubs show a very slow growth of the stem; the annual layers are often very narrow; 0.07 mm. in the case of the Azalea, so that a stem 55 years old has a diameter of only 7 to 8 mm. The comparison of the alpine rate of growth with the tropical growth is striking: in comparing a cross-section of a tropical Acacia 6 years old with the stem of our Azalea 55 years old, the growth in the Alps is seen to be 615 times slower than in the tropics.

The last link in the chain of more and more reduced dwarf shrubs is the dwarf Willow (*Salix herbacea* L.), called by Linnaeus "the smallest of all trees." It thrives in our Alps in a belt from 6,000 up to 11,000 feet above sea-level; it can reach the age of 40 years, but the whole stem and the branches are completely hidden in the ground (Fig. 18); only the tops of the twigs come above the soil, bearing two little leaves and a delicate catkin, male or female. This mat-forming tree is the strongest expression of the adaptation of a tree to high alpine conditions.

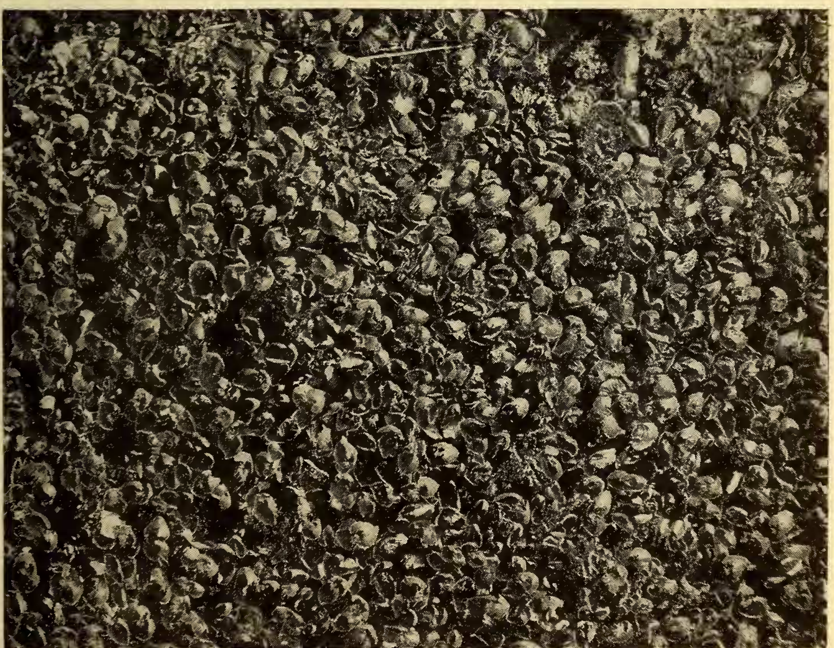

Fig. 19. "The Smallest Tree of the World"—Dwarf Willow (*Salix herbacea* L.). A pure association seen from above. The ground is completely covered with the short twigs of the plant, bearing two rounded leaves and a little catkin. The rest of the tree is hidden in the ground. "Snow Valley" at Pasture Di Lagalb, near Bernina hospice, at 2,400 meters above the sea.

Photo von Ostrom.

It likes the so-called "snow-flushes," little depressions always saturate with snow-water, where it often forms pure carpets of several square feet (Fig. 19). It belongs historically to the "Glacial Migrants," plants which have reached their present distribution under glacial conditions. It is widely distributed also in Arctic regions.

Leaving these representations of woody plants, we turn now to the herbaceous species. There we find first a group of large plants forming on humus and manured soil of herbaceous thicket ("Hochstaudenflur," or tall herb growth). They form often a typical association of chalet-plants or leger-plants, forming a luxuriant garden round the alpine huts. Only azote-loving plants not touched by cattle can live in this over-manured soil, and so we find on this fertile soil a vegetation of absolute weeds, a great drawback in the economical feature of our Alps. Experiments on the Fürstenalp near Chur in the Grisons have shown that it is possible to convert these thickets of weeds into splendid artificial meadows, and so hundreds and hundreds of acres of the best alpine soil can be added to the cultivated alpine land.

Now we tread on the continuous vegetation of the alpine pastures and meadows. The floristic composition, the plant association of this sward, depends essentially on its treatment by the alpine farmer. The master factor is here the manuring, which favors certain plants and discourages others; in a secondary manner work as a selecting factor the scythe and the pasturing of cattle. The flora of the meadow belt of our Alps is only to be understood as an effect of those artificial factors which since centuries ago operated with the same force as climate and soil.

The richest flora is to be found on those steep grassy slopes where the cattle do not have to go and where only occasionally the herder exercises his dangerous work of cutting his "Wildheu." These slopes of wild hay are the El Dorado for the botanist.

Next to these come in floristical variety the non-manured but regularly cut meadow, where often upward to 8,000 feet a luxuriant vegetation enraptures the botanist. Far more uniform in their vegetation are the manured meadows of the valleys, and the most trivial flora show in open pastures, where the tramping, pasturing, and manuring cattle exercise a triple trivializing influence. Also the soil of meadow and pasture is different: the first is smooth, the latter covered by hundreds of little depressions caused by the feet of the cattle.

We wander through the pastures in springtime; the snow begins to melt and at the edges of the snow-fields the life begins to rise. With flower-buds ready to open, the Soldanelles wait for the first breath of spring, when they pierce the thin covering of snow, aided by the sun, which, permeating the snow, warms the little brown flower-stalks. And next they open triumphantly their delicate flowerbells above the white grave, one of the most touching spectacles of the victory of life over death. In their thick leathery leaves those typical alpine spring plants have stored up a rich reserve of food in the form of thickened cellwalls, containing a soluble modification of the cellulose. All the four species of the Alps (*Soldanella montana* Mikan; *S. alpina* L.; *S. pusilla* Baumgartner; *S. minima* Hoppe) are endemic, are autochthones of our mountains. The honey secreted in the base of the flower is protected from rain and from unbidden guests by the hanging position of the flower and by little scales projecting from the corolla.

Another plant of the melting snow is the spring Anemone (*Anemone vernalis* L.), which charms us by the long silky golden hairs covering the flower and its stalks, forming a good protection against

Fig. 20.—Spring Anemone (*Anemone vernalis* L.) on Mt. Pilatus near Luzern. Photo Arnberg.

dangerous loss of water, checking transpiration (Fig. 20). We must not forget that the cold soil saturated with snow-water is "physiologically dry," because the roots cannot fully perform their duty to pump the water. So we understand the curious fact, that a plant growing in wet soil has adaptations against drought.

The spring Saffron (*Crocus albiflorus* Kit.) follows with the snow of its flowers directly after the snow of the winter; also this plant shows means to check transpiration (Fig. 21).

Fig. 21. Spring Saffron (*Crocus albiflorus* Kit.); blooming in profusion produces the effect of a flower-snow after the melting of the winter snow. Rigi-Kaltbad, 1,300 meters above the sea. Photo Gnaz.

In the alpine summer the deep blue flowers of the common bell Gentian direct themselves toward the sun. There are two representative species, the one (*Gentiana Kochiana* Perr. & Song.) on siliceous, the other (*Gentiana Clusii* Perr. & Song.) on calcareous soil (Fig. 22). The flowers belong to the revolver type: they have five different honey-holes in the ground of the corolla, each of which is to be sucked apart by the pollinating insect. And these honey cavities are illuminated from outside by the light which penetrates through windows; the botanists call this a window-flower!

The delicate short-leaved Gentian (*Gentiana brachyphulla* Vill.) has flowers which can only be pollinated by butterflies, the long and very narrow tube of the corolla excluding other insects. This category of flowers, the butterfly-flower, is very frequent in the alpine belt, owing to the relative frequency of the butterflies in the Alps. If you have once the chance to view the meadows of Upper Engadine in June, as the period of the richest flora, you will be astonished at the innumerable mass of butterflies visiting the flowers.

On the much used pastures grow often our three best forage herbs: the alpine Plantain (*Plantago alpina* L.), the Spingel (*Li-*

Fig. 22. Common Bell Gentian (*Gentiana Kochiana* Perr. & Song.), Fluela-Schwarzhorn, Grisons, 2,600 meters above the sea. Photo Guyer.

gusticum mutellina (L.) Crantz), and the alpine meadow-grass (*Poa alpina* L.). The Spingel is an autochthon element, from its aromatic qualities much sought by cattle. It has a well-developed, much branched rhizome with long subterranean creepers, so that one plant may cover some square feet. These creepers are covered with sleeping buds, forming quite a lot of reserves for replacing lost aerial shoots eaten by the cattle. This faculty of reproduction is very useful to pasture plants.

The third plant is a grass, the alpine meadow-grass; it is often what is falsely called ''viviparous.'' Instead of producing flowers and fruits, the spikelets grow directly out in a little plant, in bulbils, which, after dropping off the mother plant, take root directly, and so form a very sure and abundant means of vegetative propagation. It is a very important fact that the cattle do not touch the panicles full of young bulbils, though these would seem to be an excellent food; but in order to be able to bear the weight of all the bulbils, the stalk is so fibrous that the cattle do not like it. We see here a very instructive example of the fact that a certain structure caused directly by a mechanical stimulus becomes useful indirectly in quite another direction. Our meadow-grass is a very widely distributed circumpolar element, that lives also on the Ural, the Himalaya, and the Rocky mountains.

On sunny dry calcareous slopes we meet the most popular of alpine meadow plants, the "Edelweiss" (*Leontopodium alpinum* Cass.). The attractions of this plant, caused by its pure white color, the "noble white," and by its extremely local distribution often on steep slopes, cause more accidents than the difficult ascensions of icy

Fig. 23. Edelweiss (*Leontopodium alpinum* Cass.), Valley of Zervreila, Grisons.

peaks (Fig. 23). It is not an autochthon alpine plant, but properly an inhabitant of Asiatic steppes. It is a typical "xerophyte," protected against drought by its thick woolly covering of air-filled and therefore snow-white hairs. The so-called flower at the end of the stalk has a very intricate composition; it consists of several distinct flower heads, each with hundreds of individual flowers. These are four kinds: hermaphrodite, male, female, and honey flowers. These four different flower forms are distributed in various manners among the flower heads. The pseudoflower is rendered still more conspicuous by a beautiful white star consisting of broadened ordinary leaves, which surround the cluster of heads as an apparatus for advertisement for the insects. The white color serves here therefore for the purpose of the pollination; but its primary nature is in connection with the rôle of the hair-covering as a means of protecting the plant, with the result that a certain useful structure has become useful afterward in quite another direction.

Fig. 24. Round-leaf Penny Cress (*Thlaspi rotundifolium* (L.) Gaud.), a typical scree-creeper, emerging between the stones.
Photo Teager.

At the marshy margin of alpine lakes and ponds thrives, especially on siliceous ground, a grasslike plant of arctic origin, the cotton-grass of Scheuchzer (*Eriphorum Scheuchzeri* Hoppe). You see it here fringing with snowy fruiting heads the shallow water of little depressions between the *roches moutonnées* near Bernina hospice. The white color is also here the effect of the air-filled hairs; they accompany the fruit and serve as a flying apparatus, helping the distribution by the wind. They have nothing to do with transpiration nor advertisement, the air is here exclusively as a means for diminishing the weight.

We have now made the acquaintance of some of the principal types of meadows and pastures. We leave them to study the flora of rubbles and rocks.

The moving slopes of rubbles, the screes, have quite peculiar conditions of life for their inhabitants. The stones menace continually their shoots and the soil is distributed in little heaps on separate stones; therefore we find special adaptation in the scree-plant.

The round-leaved Penny Cress (*Thlaspi rotundifolium* (L.) Gaudin) (Fig. 24) is one of the most constant inhabitants of moving débris; never do we find it on the pasture. The special method of avoiding the dangers of its habitat consists in spreading with long flexible creepers through the gaps between the loose stones, here and there sending out rootlets where it finds a little sediment of detritus. With isolated aerial shoots it emerges from the rubbles to unfold its roundish leaves and its violet flowers. The plant is an endemic product of our Alps. In similar manner the bluebell of Mt. Cenis (*Campanula cenisia* L.) penetrates with long shoots the narrow gaps in the rubble slopes.

Fig. 25. White Alpine Poppy (*Papaver alpinum* L. var. *Sendtneri* Kerner), in limestone screes at the Pilatus near Luzern, 1,900 meters above the sea. Photo Guyer.

The beautiful alpine Poppy (*Papaver alpinum* L. var. *Sendtneri* Kerner) follows another system of resisting the menacing soil movements of its habitat, opposing itself with big clusters of crowded roots against the moving stones (Fig. 25). It is a rare inhabitant exclusively of calcareous débris. It is a delicious spectacle to see hundreds and hundreds of little islands between the bare stones garnished with their delicate white flowers.

One of the saxifrages, the genus so rich in alpine species, the purple Saxifrage (*Saxifraga oppositifolia* L.), is widely Arctic-Altai element of the alpine flora, using the two modes of growth, creepers and compact clusters. It has wandered once in the glacial time with the increasing glaciers to the foreland of the Alps; and after the glacial epoch, as the glaciers retreated to their present state, it has subsisted in isolated colonies upon the gravel along the shore of the Lake of Constance, as a typical glacial relic.

Another kind of alpine débris, a resting flat stony soil, saturated with snow, is inhabited by some high alpine plants, the Gentian (*Gentiana bavarica* L.) (Fig. 26) and the glacial Buttercup (*Ranunculus glacialis* L.). The buttercup is a circumpolar arctic element; it forms often true gardens of white and rose flowers in absolutely glacial conditions, up to 14,250 feet, the absolute upper limit of flowering plants in Switzerland (Fig. 26). It is a noticeable fact that this most resistant plant shows no visible adaptation to the extreme conditions of its glacial stations; it has a smooth somewhat fleshy stem, glabrous leaves, forms no cushions: we have here one of those instructive cases where the power of resistance lies in the constitution of the living substance, is purely physiological, and shows no morphological expression. Similar stations upon wet sand in the high alpine belt are adorned with the rose cushions of Androsace alpina (L.) Lam.

The last ecological group of the alpine plants are the rock-plants, the inhabitants of bare rocks. We can here distinguish, after the mode of fixing itself upon the rock, two sub-groups: Lower (cryptogamic) plants, lichens and algae, are clinging directly to the bare rocks, perforating its surface with their stone-dissolving cells, aiding erosion, preparing the soil for higher plants. The other group, including mosses, ferns, and flowering plants, is confined to the sediments of detritus in fissures or upon little bands of rock (chomophytes).

One of the most exclusive of our alpine rock-plants is the rock-Potentilla (*Potentilla caulescens* L.), which thrives only in the fissures of vertical rock-walls, penetrating deeply the rock and forming in the fissures often quite a texture of entangled rootlets. It has no adaptation at all against drought; it is a typical mesophyte, and therefore a proof of the fact that rock stations are not necessarily dry ones; the rock on the contrary is often quite a reservoir of water. Also the yellow Primula (*Primula auricula* L.) is confined to calcareous rocks.

Fig. 26. A typical association of high Alpine plants on humid screes of granite at the Vereinapass, Grisons, 2,600 meters above the sea. *Cerastium uniflorum* Murith. *Ranunculus glacialis* L. *Gentiana bavarica* L. var. *imbricata* Schleich. *Chrysanthemum alpinum* L.

A very typical group of rock-plants are the cushion-plants, forming thick hemispherical cushions, covered with short-stalked and closely adhering flowers. Their twigs radiate from a center; they are thickly covered with little closely-set leaves, which remain withering on the stem, filling the whole interior of the cushion with decaying material, forming a sort of spongy mine of humus. The living leaves form a continuous covering over the compact interior, and are hairy or leathery. The whole structure of these cushions is to be understood as a manifold protection against drought and intense wind: transpiration is checked by the hairy or leathery structure of the leaf, by the low growth near the soil, where the wind is less intense, and by the compact structure of the interior. The spongy mass of humus forming the interior with its thousand and thousand capillary cavities works as a sponge retaining the water; it holds the soil underneath in a damp state and prevents high temperature.

We find the cushion form in many plants of seemingly very different stations. On the stormy treeless shores of the sub-antarctic islands, especially Kerguelen, grow cushions of some meters in diameter (*Bolax gumifera* (Lam.) Spreng.); on the wet but cold peat-moors of the Andes, as well as in the dry hot sands of the Sahara, we find cushions; on crests and summits; so especially the Swiss Androsace (*Androsace helvetica* L.) exclusively found in the calcareous Alps, an autochthon product of them and much more characteristic of our Alps than the Edelweiss.

On the whole earth we find 338 species of cushion-plants in 34 different families. That is a classical example of convergence of the fact that plants from the most different families adopt very similar habits through the influence of similar conditions. Indeed, if we compare the different stations cited above, they are all, for plant life, to be characterized as dry, as menacing the plant with drought. Their soil can well contain much water, be physically wet; but this water is only with difficulty available for the plant (retained by humus or because the soil is cold). The soils are physiologically dry (peat moors, cold alpine soils), or the stations are exposed to constant loss of water by intense wind; so on the wind deserts of the sub-antarctic islands and on the exposed summits of the Alps. Here in the Alps especially the winter with its dry air and frozen soil becomes a danger so much the more as many of our alpine cushions, especially the Swiss Androsace, prefer the most exposed positions where the snow is constantly blown away.

I come to the end; I wish finally to recall to you that we have convinced ourselves that the total features and entire household of alpine plants is a most faithful expression of alpine conditions of life. The principal characteristics of the alpine flora, the dwarfy growth, are of a double nature; on one hand they are direct effects of climate by means of plentiful light and the cold nights, on the other hand the dwarfy growth is indirectly favored as a protection against snow and wind, and as a means of better utilization of the warmth of the soil and the greater dampness of the atmosphere near the soil. The anatomical structure of the leaf shows many relations to a greater assimilatory power in connection with the intense light. The leaf is thicker, has well-developed palisade cells, many breathing pores, abundance of chlorophyll, many intercellular spaces; in short, it is a typical sun-leaf. The temporarily great power of evaporation of the air and the intense wind cause manifold zerophytic adaptations; an extreme one is the cushion habit.

The short period of vegetation stands in relation to the rareness of annual plants, because they have difficulty to ripen from seed to seed in the short summer. It causes also the great percentage of evergreens, which in spring are at once ready to assimilate. It favors early flowering; it causes the small annual layers of woody plants. We understand the brightness, the dominance of the flowers in comparison with the green body of the plant in considering the factors which reduce the vegetative organs have no reducing effect on the flowers. Also the intense light and the selecting influence of the pollinating insects play here a certain rôle.

So we gain by the study of the alpine flora an insight in the narrow connections between the living nature and the surrounding factors. He who has an open eye for these fascinating studies will have a double enjoyment in rambling through the lofty scenery of the mountains.